

The University of Chicago

QUANTITATIVE STUDY OF
ETHYLENE PRODUCTION IN RE-
LATION TO RESPIRATION
OF PEARS

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE BIOLOGICAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR OF
PHILOSOPHY

DEPARTMENT OF BOTANY
1946

By
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THE BOTANICAL GAZETTE
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QUANTITATIVE STUDY OF ETHYLENE PRODUCTION IN RELATION TO RESPIRATION OF PEARS¹

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 538

ELMER HANSEN

(WITH SEVEN FIGURES)

Introduction

Recent investigations have shown that volatile substances other than carbon dioxide are produced by apples (2, 4), pears (8), and certain other fruits (15). These emanations, although present in minute amounts, have been found to influence the respiration and other metabolic activities associated with ripening processes. That the active principle concerned with producing these effects is ethylene has been established definitely (3, 9, 20). In view of these findings, the factors associated with the formation of ethylene in fruits and its production in relation to other phases of metabolism have been studied.

GANE (4) has measured the quantity of combustible emanations from Marie Louise pears and found that the amounts produced increased rapidly at the climacteric. With apples he found some indication that the more rapidly respiring varieties were in general more active in the production of volatiles. KIDD and co-workers (12) have estimated by combustion the total carbon-containing substances other than CO₂ which are evolved during the ripening of Conference pears stored at 10° C. and found that the maximum rate of production of these emanations corresponded to the maximum of the initial rise in respiratory activity. They did not find that this increase was due to an increase in the rates of escape of alcohol and acetaldehyde. GERHARDT and EZELL (5), using concentrated sulphuric acid as an absorbent, studied the emanation of volatiles in relation to respiration of Bartlett pears during ripening at 65° F. and found that the climacteric for respiration preceded that for total volatiles by approximately 7 days. They state, however, that a considerable portion of the emanations from fruits of this variety may result from the gross liberation of acetaldehyde from the tissues.

The development of microchemical methods (1, 16, 20) for the determination of ethylene has made it possible to isolate ethylene from all other volatile compounds produced by fruits and to estimate it separately. NELSON (16), by use of a potassium-permanganate oxidation method, has made a quantitative study of ethylene production by apples and bananas and has shown that an apparent

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relationship exists between the keeping qualities of apples and the amounts of ethylene which they produce.

The present investigation was undertaken for the purpose of making a quantitative study of ethylene production in relation to respiration of pears. The emanation of this gas during ripening in air at 20° C.—and under conditions by which respiration was altered by changes in temperature and oxygen tension—has been studied.

Material and methods

SOURCE AND HANDLING OF FRUIT.—The three varieties of pears—Bartlett, Doyenne du Comice, and Beurre d'Anjou—used in this investigation were obtained from the Medford, Oregon, district. The fruit was picked at the regular commercial picking date for the variety, packed in oil wraps, and stored at 0° C. (32° F.). During the fall of 1939, the fruit was shipped under refrigeration to the University of Chicago, where the experimental work for the first season was carried out. The methods used in handling the fruit after removal from cold storage varied with different lots, as later specified.

ANALYTICAL METHODS.—The method for determining the CO₂ and O₂ of respiration was that of HALLER and ROSE (7) as modified by MASURE (14). Approximately 2.5 kilograms of fruit were inclosed for 15–20 hours each day in large desiccators. Oxygen was supplied from calibrated 2.5-liter bottles connected to the desiccators by means of 1-mm. capillary tubing. The oxygen inlets were fitted with mercury valves to prevent backward diffusion of air and the evolved ethylene into the oxygen-supply bottle. The fruit was held at 20° C. (69° F.) during ripening, except for certain experiments as later specified. The use of this method (in which the fruit is kept in a confined air space) made it possible to determine CO₂, O₂, and ethylene on the same fruit sample. In this procedure the evolved ethylene accumulates in the desiccators during confinement of the fruit, and this fact must be taken into consideration in interpreting any data obtained. The recent work of KIDD and WEST (11) and HULME (10), however, has shown that mass lots of fruit cannot be kept free from ethylene, even where ventilated, so that it tends to exert an effect under any method used unless individual fruits are kept isolated from one another.

Ethylene was estimated by the micro-bromination method previously described (1, 9). In order to utilize a larger gas sample for analyses than originally specified, the following modified procedure was used. After an aliquot of the potassium-hydroxide solution had been withdrawn for titration, the desiccator was connected to a 220-ml. gas-sampling bulb and a sample of air for ethylene analysis withdrawn. Then 0.2 ml. of 28 per cent ammonium-hydroxide solution was introduced from a pipette connected to the side arm of a three-way stopcock on the lower end of the sampling bulb by means of a short piece of rubber tubing. The

leveling bulb was then raised and the ammonia—together with approximately 10 ml. of mercury—was allowed to mix with the gas sample. The bulb was then shaken and allowed to stand for 15 minutes to insure complete absorption of any acetaldehyde present. A portion of the gas sample was finally passed slowly through the purification unit, as previously described, and collected over mercury in a 100-ml. gas burette.

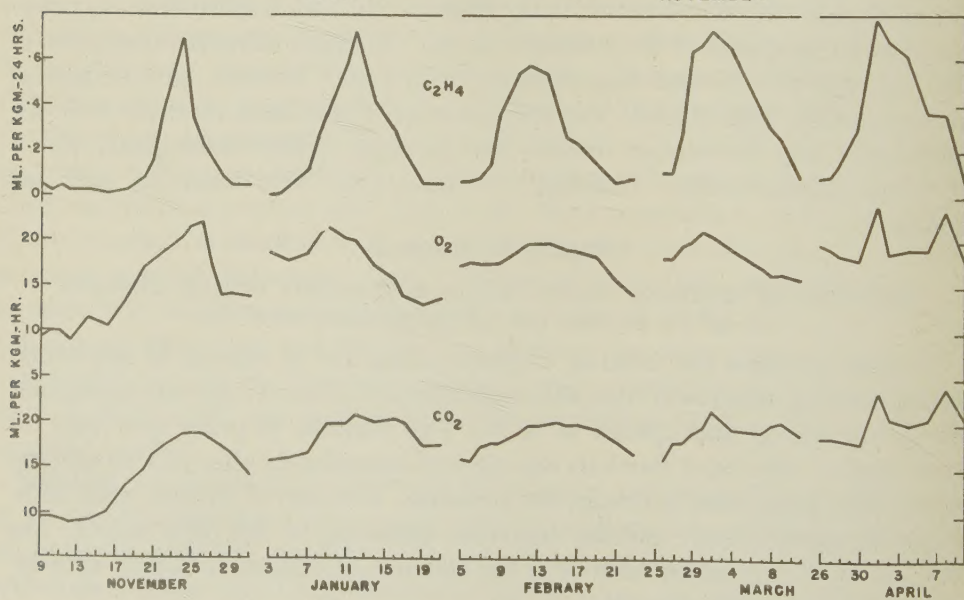
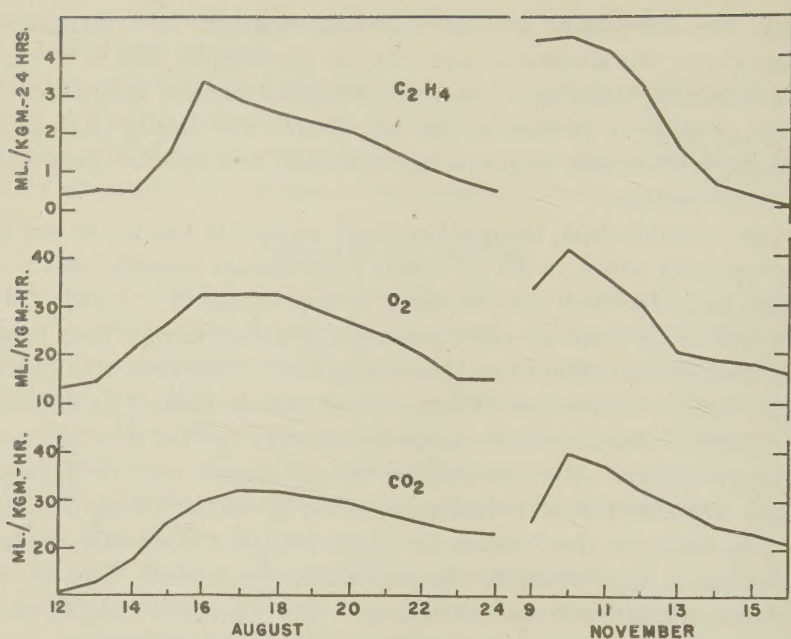
To a 125-ml. reaction flask, identical in design except for size to the one previously described, was added 10 ml. of 0.0025 N potassium bromate and 1 ml. of 6 N sulphuric acid. The flask was evacuated to approximately 27.5 inches of mercury, connected to the burette, and the purified ethylene sample then drawn in by opening the stopcocks and raising the leveling bulb. Since mercury brominates readily, care was taken to prevent its introduction into the flask. To guard against this, a short piece of ordinary tobacco pipe-cleaner was inserted into the capillary outlet of the gas burette. After introducing the gas sample, 2 ml. of N/10 potassium bromide was added from a pipette connected by rubber tubing to the reaction flask. The flask was then shaken for 15 minutes on a horizontal mechanical shaker operating at approximately 100 oscillations per minute. Two ml. of 2.5 per cent potassium iodide was then introduced. After vigorously shaking the solution, a wash bottle was connected to the flask and the neck washed down by drawing in water by means of the residual vacuum. To insure complete absorption of the free bromine, the flask was allowed to stand for 2 minutes, with occasional gentle rotation. The stopcock was then removed, rinsed down carefully with distilled water, and the solution titrated with 0.0025 N sodium thiosulphate from a 10×0.02 micro-burette. Duplicate determinations were made on each gas sample.

Experimental results

RELATION OF ETHYLENE PRODUCTION TO RESPIRATION DURING RIPENING AT 20° C. BEFORE AND AFTER STORAGE AT 0° C.

In order to follow the trend of ethylene production in relation to respiration during ripening, samples of fruit were withdrawn at different intervals throughout the storage period and ripened at 20° C. Two varieties of pears were used for these studies. One lot of Bartletts was ripened immediately after picking and the second after being held in storage for 3 months. Five lots of Anjous were withdrawn at approximately monthly intervals, beginning on the third month. The CO_2 and O_2 of respiration, as well as the amounts of ethylene evolved, were determined daily during ripening.

The Bartlett pears ripened immediately after picking showed a low rate of respiration as well as emanation of ethylene at the beginning of the experiment (fig. 1). Both processes began to increase at the same time, but the peak in ethylene production was reached one day earlier than the maximum for respiration.



FIGS. 1, 2.—Fig. 1 (top), ethylene production and respiration of Bartlett pears during ripening before and after storage at 0°C . Fig. 2 (bottom), ethylene production and respiration of Anjou pears during ripening after progressive storage periods.

During the post-climacteric period, ethylene production and oxygen consumption fell off rapidly, while the production of CO_2 showed a much slower rate of decline. The ratio CO_2/O_2 changed markedly during the course of ripening. At the beginning the value was approximately 0.8. At the climacteric, when the fruit was fully ripe, it had increased to unity but rose to 1.4 at the termination of the experiment. These wide changes in the respiratory quotient indicate that qualitative as well as quantitative changes occur in respiration during ripening.

The sample of Bartlett pears held for 3 months in cold storage was still fairly firm but had begun to show a yellow color when withdrawn for ripening. The fruit became fully ripe after being held for 4 days at 20°C . The curves for respiration and ethylene production for this lot differ in some respects from those of the fruit ripened immediately after picking. The peak in respiration was reached on the second day as compared with the fifth day for the first lot. Ethylene production was at a maximum on the second day and declined steadily thereafter, finally falling below the amount that could be quantitatively measured.

The data for the Anjou pears are presented in figure 2. In the first lot ripened, ethylene production remained at a very low level (0.009–0.03 ml. per kg./24 hour) for 7 days before a steady rise began. During the following 6 days there was a twenty-three-fold increase, followed by a sharp decline when the fruit became overripe. The curves for samples of fruit ripened at later dates are similar, except that the increase in ethylene production began immediately on transfer to the higher temperature.

Certain differences were observed in the trend of respiration during ripening of fruit withdrawn at different dates during the storage period. In the first sample, CO_2 output and O_2 intake remained at a low level for 7 days and then approximately doubled during the following 6 days. The peak in respiration coincided very closely with the peak in ethylene production. For the samples of fruit withdrawn at later dates there was a steady increase in the initial rates of CO_2 production and O_2 consumption, so that the sharp incline characteristic of the climacteric rise was of shorter duration. In the last sample of fruit ripened, a secondary increase in respiration occurred during the post-climacteric period. No increase in rate of ethylene production occurred during this final rise in CO_2 output and O_2 intake. KIDD and co-workers (12) have reported that total combustible volatiles of Conference pears do not increase during the secondary rise in respiration.

Table 1 presents the initial and maximum rates of evolution of CO_2 and ethylene for each lot of fruit ripened at the different dates during the storage period. The relative increases, calculated as maximum rate/initial rate, are also given.

The data of table 1 indicate certain well-defined trends for respiration and for ethylene production during storage and ripening. There is a progressive increase

in the initial rate of respiration for each lot of fruit when removed from cold storage to warm temperature. In the Bartletts this increase was from 11.61 to 25.90 ml. per kg.-hour, and in the Anjous from 9.45 to 18.23 ml. per kg.-hour. The initial rates of ethylene production likewise showed distinct indication of increasing. In Bartletts the range was from 0.49 to 4.39 ml. per kg.-day and in Anjous from 0.009 to 0.12 ml. per kg.-day. As shown in the table, the relative increases during the climacteric are much greater for ethylene production than for respiration. This may indicate that the two processes are not directly related. Additional evi-

TABLE 1
INITIAL AND MAXIMUM RATES OF CARBON DIOXIDE AND ETHYLENE PRODUCTION
AT 20° C. AFTER DIFFERENT PERIODS OF STORAGE AT 0° C.

MONTHS STORED	RATE OF RESPIRATION (ML. PER KG.-HOUR)			RATE OF ETHYLENE PRODUCTION (ML. PER KG.-DAY)		
	INITIAL	MAXIMUM	INCREASE	INITIAL	MAXIMUM	INCREASE
BARTLETT						
0.....	11.61	33.03	2.85	0.490	3.25	6.63
3.....	25.90	39.89	1.54	4.390	4.48	1.01
ANJOU						
2.....	9.45	18.79	1.99	0.009	0.700	78.80
4.....	15.76	20.72	1.31	0.010	0.726	72.60
5.....	16.03	19.89	1.24	0.065	0.570	8.77
6.....	15.60	21.00	1.35	0.105	0.761	7.25
7.....	18.23	23.27	1.28	0.120	0.782	6.52

dence in favor of this view is shown by the wide varietal differences in respiratory activity and ethylene production. The maximum rate of respiration for Bartlett pears is approximately double the rate for Anjous, yet the maximum rate of ethylene production is six or seven times greater in Bartletts than in Anjous.

The production of ethylene in relation to respiration during ripening of pears is distinctly different from that for apples and bananas as reported by NELSON (17, 19). He found that during the climacteric for these fruits, ethylene production decreased but increased again in the post-climacteric stage. Thus there was an inverse correlation between the emanation of ethylene and the production of CO₂. He suggested that ethylene was "consumed" during respiration and presented experimental evidence to that effect (18). If ethylene is metabolized during respiration of pears, the highest rate must occur when respiratory activity is low,

since the highest rates of ethylene production were found to coincide with the highest rates of respiration. No experimental evidence could be obtained, however, that ethylene is oxidized or otherwise metabolized by pears when respiratory activity is either high or low. Pure ethylene in small amounts was added to a desiccator containing Anjou pears in all stages of ripeness. There was an initial loss during the first 2 hours, probably due to adsorption of the gas on the glass walls and diffusion into the fruit; no further loss could be detected. The apparent discrepancies found between the emanation of ethylene and the respiration of pears cannot be explained on the assumption that ethylene is metabolized by the fruit.

No explanation is apparent at the present time for the differences in the relation of ethylene production to respiration of pears and apples. The time relation for the occurrence of the climacteric is different for the two fruits, and this fact may have some bearing on the discrepancy found. In apples (as well as in bananas) the climacteric precedes actual ripening of the fruit. In pears, however, ripening begins with the climacteric rise, and at the initial respiratory maximum the fruit is fully ripe.

PRODUCTION OF ETHYLENE IN RELATION TO RESPIRATION UNDER CONDITIONS OF ALTERED TEMPERATURES AND OXYGEN CONCENTRATIONS

The data presented in the previous section have shown that ethylene production and respiration do not follow precisely parallel courses during ripening at 20° C. Since respiration can be altered by several experimental treatments, the production of ethylene under similar treatments was investigated.

The production of ethylene when fruit is maintained under anaerobic conditions was investigated first. For this experiment, three lots of Bartlett pears which had been in storage for 3 months were used. The fruit was kept in air for the first day. On the second day the air in the several desiccators was displaced with nitrogen, hydrogen, and helium, respectively. On the third day all lots were again transferred to air. Determinations of CO₂ and ethylene were made daily.

It is apparent from the results obtained (fig. 3) that the emanation of ethylene is not associated with the production of CO₂ under anaerobic conditions. Upon transfer of the fruit to oxygen-free atmospheres, ethylene production was either greatly retarded or totally inhibited. When transferred to air, emanation again took place. The production of CO₂ under aerobic and anaerobic conditions, however, changed very little.

This experiment was repeated the following season on newly-picked Bartlett pears. One lot of fruit was kept for 3 days in air, transferred to nitrogen on the fourth day, and then maintained in air for an additional 5 days. A second lot was kept continuously in air. The results are shown in figure 4.

The sample of fruit confined continuously in air showed the usual climacteric rise and increase in ethylene production followed by the sharp decline shown previously for pre-climacteric pears. The behavior of the treated lot, however, was decidedly different. On transferring the fruit from air to nitrogen, the rate of ethylene production declined below the amount quantitatively determinable. Respiration as measured by CO_2 showed very little change. On transfer from nitrogen to air, ethylene production increased to slightly above the maximum rate for the control fruit, and thereafter ethylene production in both lots declined at approximately the same rate. The production of CO_2 , on the other hand, declined

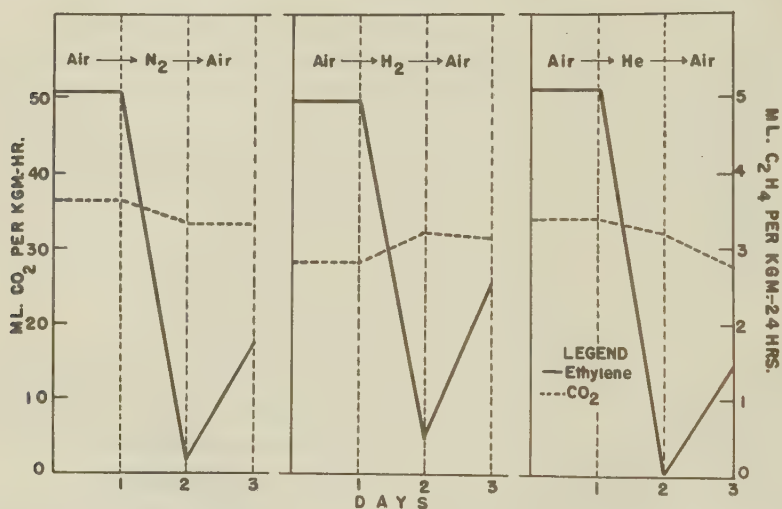


FIG. 3.—Comparative production of ethylene by Bartlett pears under aerobic and anaerobic conditions.

the first day following nitrogen treatment, then increased slightly before showing the senescent decline. The striking feature shown in this experiment is that subjecting the fruit to anaerobic conditions for 1 day prevented completion of the climacteric rise. In spite of this fact, ethylene production rose from zero to slightly above the maximum rate shown by the fruit held continuously in air. It has been possible, therefore, experimentally to decrease the magnitude of the climacteric without altering the usual trend of ethylene production.

The effect of temperature on respiration and ethylene production was also investigated. For these experiments Comice pears which had been kept in storage for 2 months were used. The fruit was brought directly from 0°C. storage, carefully sorted into five uniform lots, and then placed in constant temperature cabinets maintained at 0° , 10° , 20° , 30° , and 40°C. , respectively. After the temperature of the fruit had reached the respective air temperature, it was placed in

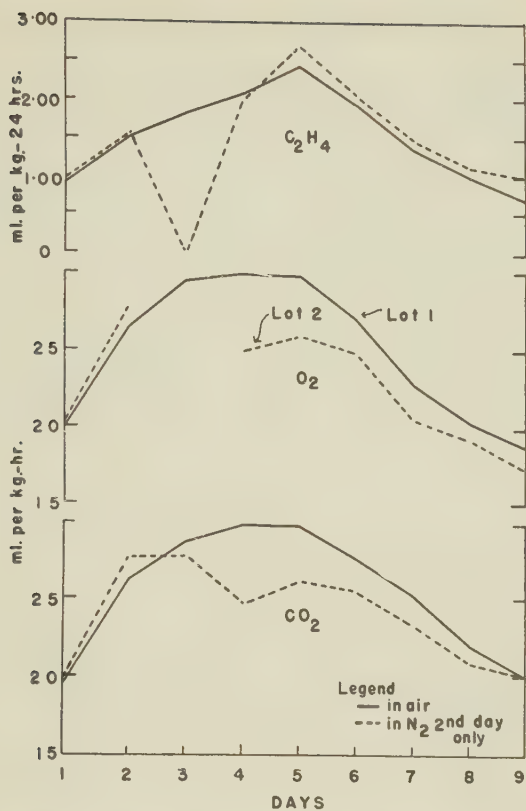


FIG. 4.—Effect of nitrogen storage of Bartlett pears on subsequent production of ethylene and respiration in air. Lot 1 held continuously in air at 20° C. Lot 2 transferred to nitrogen on second day but held continuously in air thereafter.

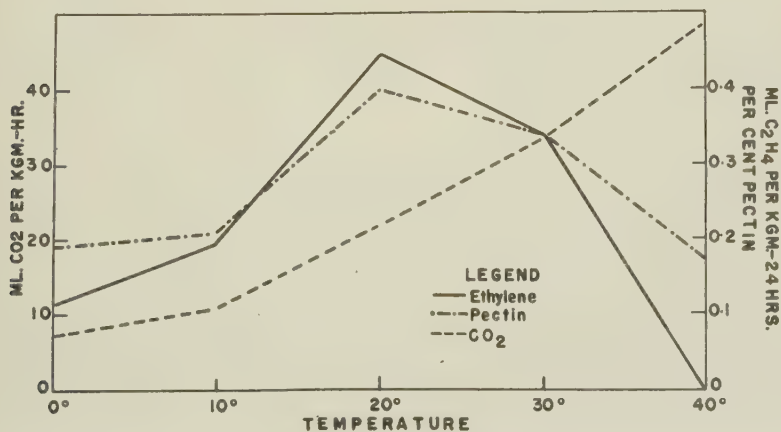


FIG. 5.—Effect of temperature on ethylene production, respiration, and pectin formation in Comice pears.

desiccators and supplied with oxygen as previously described. Determinations of CO_2 and ethylene were made after 24 hours. One-half of each lot was then used for the determination of the internal concentration of CO_2 and O_2 . The remainder of the fruit was kept for an additional 5 days for soluble pectin analyses.

That changes in temperature do not affect ethylene production and respiration to the same degree is apparent from the data obtained (fig. 5). Between 0° and 20° , ethylene and CO_2 production both increased, the former reaching a maximum at the higher temperature. From 20° to 40° , CO_2 production continued to increase steadily but the rate of ethylene evolution declined sharply, reaching a zero value at 40° . The rate of soluble pectin formation also increased up to 20° , but declined thereafter. It is known from previous experiments (21) that the ripening of pears

TABLE 2
EFFECT OF TEMPERATURE ON CO_2 AND O_2
CONTENT OF COMICE PEARS

TEMPERATURE ($^\circ\text{C.}$)	PERCENTAGE CO_2	PERCENTAGE O_2
0.....	9.99	26.61
10.....	18.56	16.19
20.....	23.33	12.62
30.....	30.50	6.57
40.....	27.50	4.51

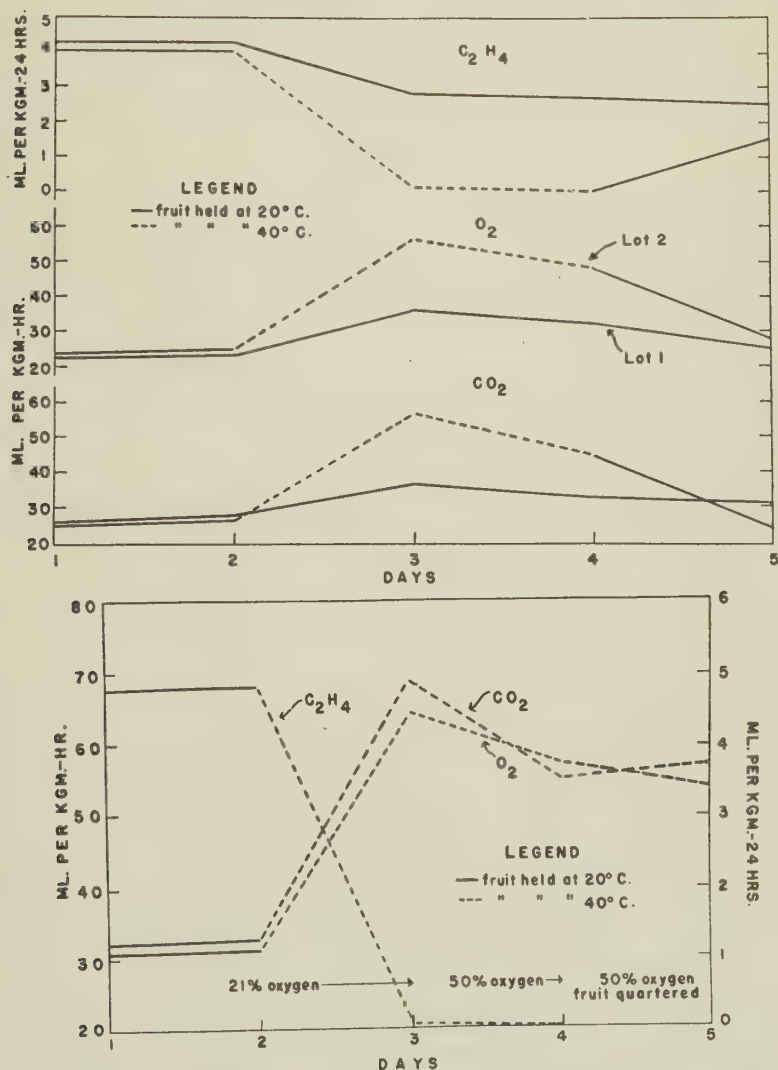
is retarded by high temperatures, but the significant fact shown in the present experiment is that ethylene production is similarly retarded.

The data presented in table 2 show that with increase in temperature there is an increase of CO_2 and a decrease of O_2 in the fruit tissues. From these data it could be assumed that at high temperatures, oxygen became a limiting factor so that no ethylene was produced. To investigate this possibility, the following experiments with Bartlett pears were carried out. One lot of fruit was maintained continuously at 20° during ripening. A second lot was kept for 2 days at 20° , then transferred to 40° for 2 days, and finally returned to 20° for 1 day. Oxygen consumption in addition to ethylene and CO_2 production was measured daily.

As shown in figure 6, ethylene production declined from approximately 4 ml. per kg.-day to zero on transfer of the fruit to the higher temperature. In contrast, respiration as measured by either CO_2 or O_2 greatly increased, the RQ being slightly greater than unity at 40°C . When transferred to 20° , emanation again occurred, showing that destruction of the ethylene precursor or enzyme system had not taken place.

In a second experiment the effect of increasing the concentration of oxygen in fruit held at 40° was investigated. The first day the fruit was confined in air.

The second day the same oxygen concentration was maintained, but the temperature was raised to 40°. On the following day the concentration of oxygen was in-



FIGS. 6, 7.—Fig. 6 (top), effect of temperature on ethylene production and respiration of Bartlett pears. Fig. 7 (bottom), effect of increasing oxygen tension of Bartlett pears held at 40° C. on ethylene production and respiration.

creased to 50 per cent. On the final day at the higher temperature the fruit was cut into quarters but retained in 50 per cent oxygen.

The data (fig. 7) show that increasing the oxygen concentration to 50 per cent

or increasing the absorptive surface by quartering the fruit had no effect on ethylene production at 40°. There was a small amount of ethylene found the first day on transfer to high temperature, but the production dropped to zero thereafter. Oxygen consumption as well as CO₂ production increased with rise in temperature, clearly demonstrating that aerobic respiration was taking place. In spite of this fact, no ethylene was produced. It could be assumed that probably the high content of CO₂ in the tissues inhibited ethylene production, or that ethylene was metabolized by the fruit when kept at high temperatures. Both these possibilities were investigated but with negative results. Ethylene production was found to be retarded but not inhibited in a mixture of 33 per cent CO₂ and 21 per cent O₂. Nor could any loss of ethylene be detected at 40° when small amounts of the gas were added to the desiccator according to the method used by NELSON (18).

Analysis of the gases extracted from pears kept at 40° showed no ethylene present. The addition of synthetic ethylene to fruit maintained at high temperatures, however, did not have any effect on ripening, the fruit remaining hard and green after 6 days' treatment. These data show that the mere presence of ethylene in the tissues is not sufficient to bring about ripening of the fruit under these conditions. Apparently the specific reaction from which ethylene is formed as a product must take place when the fruit ripens.

EFFECT OF H₂S AND HCN AS RESPIRATORY INHIBITORS

The data presented in the previous section strongly indicate that ethylene production is associated with a special oxidative system which is inhibited by high temperature. The amount of oxygen required for the functioning of this system apparently is smaller than could be detected or accurately measured by the methods used. Since certain of the oxidative enzymes are known to be inhibited by such substances as H₂S and HCN, response of the specific enzymes associated with respiration and ethylene production might differ in relation to these reagents. To investigate this possibility, Anjou pears in the post-climacteric stage were treated with H₂S and HCN in concentrations ranging from 0.1 to 4 per cent. The results obtained from these experiments have been inconclusive. Neither ethylene production nor oxygen consumption was affected by these reagents at the low concentrations found to be effective on other kinds of plant structures. At higher concentrations than those generally used, both oxygen uptake and ethylene production were partially inhibited. In one experiment a concentration of 4 per cent H₂S completely inhibited ethylene production and greatly retarded oxygen consumption. The fruit, however, showed severe injury after 2 days' exposure and did not ripen when treatment was terminated. The only conclusion that can be made at the present time from these data is that fruit in the post-

climacteric stage is not sensitive to the low concentrations of H_2S or HCN found to retard respiration in other kinds of tissues. It is possible that the reaction of enzymes to these substances is not the same at all stages of development of the fruit. MARSH and GODDARD (13) found the respiration of young carrot leaves to be inhibited by NaN_3 , HCN , and CO , but when the leaves became older the respiration was not affected by any of these poisons.

Discussion

The quantitative data obtained during the course of this investigation show that the production of ethylene is a definite part of the metabolism of mature pears. If the formation of ethylene resulted from a chance reaction, then it would be expected that emanation of the gas would be erratic and follow no well-defined trend. This has not been found to be the case. Each sample of fruit ripened at 20°C . showed the same general trend of production—an initial increase during the climacteric rise, the attainment of a maximum rate, and a decline during the senescent period. Moreover, each of the varieties studied over an extended period was found to have a definite, characteristic maximum rate of production, and this value varied but little among the different lots of fruit ripened. It may be concluded that the formation of ethylene is an integral part of the metabolic activities of mature pears. This fact is significant in that it forms the basis for the consideration of ethylene production in relation to other phases of fruit metabolism.

Determinations of the rate of ethylene production and of respiration were carried out simultaneously on the same samples of fruit. The results show that the two processes follow somewhat the same general trend during ripening, but no indications that ethylene production is directly related to respiration were found. In the first place, the relative increase in ethylene production during the climacteric rise is out of all proportion to the increase in the rate of respiration as measured by either CO_2 or O_2 . Thus, respiratory activity approximately doubles during this initial stage of ripening, while ethylene production increases seven- to eighty-fold, depending upon the variety and length of time it has been held in cold storage prior to ripening. During the post-climacteric stage, the emanation of ethylene declines rapidly, but respiration, especially as measured by CO_2 , declines at a much slower rate. Moreover, the last sample of Anjou pears ripened late in the storage season showed a secondary rise in respiration during senescence, but this was not accompanied by a similar rise in ethylene production. Additional evidence that the production of ethylene and respiration are not necessarily directly related is shown by the wide differences in the ratio $\text{CO}_2/\text{C}_2\text{H}_4$ for the two varieties of fruit studied. During the climacteric, Bartlett pears respire at approximately double the rate for Anjou, yet the rate of ethylene production is six or seven times greater in the former variety.

When pears were subjected to experimental alterations in oxygen tension and temperature, ethylene production and respiration were found to become even more widely separated. In oxygen-free atmospheres the formation of ethylene was either greatly retarded or entirely inhibited. In contrast, the rate of CO_2 evolution was changed but little by this treatment, showing that the formation of ethylene is not correlated with CO_2 production under anaerobic conditions.

Further evidence that ethylene production and respiration are not directly related is shown by their difference in response to high temperatures. From 0° to 20° C., the Q_{10} for the two processes was found to be approximately the same. At higher temperatures, however, the responses were entirely different. Respiratory activity continued to rise with increase in temperature beyond 20° . On the contrary, ethylene production declined rapidly, and at 40° C. no emanation could be quantitatively detected. That oxygen supply is not a limiting factor under these conditions has been shown. Thus, even though the rate of aerobic respiration was greatly accelerated at 40° , the production of ethylene was entirely inhibited, apparently by the inhibition of the reactions associated with its formation.

Since there appears to be no positive correlation between ethylene production and respiration under either anaerobic or aerobic conditions, it seems necessary to postulate that the formation of ethylene is not directly associated with that phase of respiration responsible for the major portion of the CO_2 produced and O_2 consumed. It can by no means be assumed, however, that the method of formation of ethylene is to be considered as entirely separate and distinct from the respiratory mechanism in fruits. Respiration in fruits, as in certain other plant structures (6, 22), may consist of several distinct but interrelated systems—some requiring oxygen, others not; but each contributes to the total amount of CO_2 being measured. According to this concept, the total amounts of O_2 consumed or CO_2 produced by the fruit will not necessarily be correlated with the activity of each individual system of the respiratory complex.

Summary

1. A quantitative study of ethylene production in relation to the respiration of pears has been made. The emanation of ethylene in air at 20° C., as well as at higher and lower temperatures in modified atmospheres, has been studied.

2. In fruit in air at 20° C. the rate of ethylene production increases during the climacteric rise in respiration, reaches a peak at the respiratory climax, then declines during the post-climacteric period. During the climacteric rise, ethylene production increases seven- to eighty-fold, while rate of respiration approximately doubles.

3. Each variety was found to have a characteristic maximum rate of production. The maximum rate for Bartlett, a variety which maintains its capacity to

ripen for only a short period of time when kept at a storage temperature of 0°C ., is 3.25–4.48 ml. per kg.-day. The maximum rate for Anjou, a variety which maintains its capacity to ripen for a long period of time when kept at cold storage temperatures, is 0.57–0.78 ml. per kg.-day. The maximum rate of respiration for Bartlett is approximately double that for Anjou.

4. Under anaerobic conditions, the production of ethylene is either greatly retarded or entirely inhibited. In the fruits used for these experiments, there was found but little difference in the production of CO_2 under aerobic and anaerobic conditions.

5. The maximum rate of ethylene production occurs at 20°C . At higher temperatures production decreases and is totally inhibited at 40°C . Respiratory activity as measured by either CO_2 production or O_2 consumption is greatly accelerated between 20° and 40°C .

The writer expresses his thanks to Dr. C. A. SHULL and others of the botany department of the University of Chicago for their assistance, and to Professor F. C. REIMER, Superintendent of the Southern Oregon Experiment Station, for supplying the fruit used in this investigation.

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